UMass Participation in Air-Sea Flux Estimation in High Wind Boundary Layers

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LONG-TERM GOALS

Our primary goal is to contribute to our understanding of air-sea surface flux processes in high winds, specifically in the complex conditions of tropical hurricanes through the development and application of microwave remote sensors.

OBJECTIVES

Our scientific objective is to collaborate with and support Dr. Peter Black and Co-investigators to meet the goals set forth in the proposal entitled, Air-Sea Flux Estimation in High Wind Boundary Layers (ONR Award #N00014-01-F-009). In particular, we will provide continuous surface wind vector and wind stress measurements as well as atmospheric boundary layer (ABL) vertical wind profiling in large wind speed gradient regimes such as storms and hurricanes through the use of microwave remote sensing instruments.

APPROACH

To meet our objective, we upgraded the current version of UMass' scatterometers, CSCAT and KUSCAT, to image the 3-D atmospheric boundary layer (ABL) winds by acquiring Doppler/reflectivity profiles of precipitation simultaneously at four separate incidence angles (approx. 30, 36, 42 and 50 degrees) while conically scanning. This modified version of scatterometers, referred to as IWRAP (Integrated Wind and Rain Airborne Profiler), is flown with an improved version of the UMass Simultaneous Frequency Microwave Radiometer (USFMR) on the NOAA N42RF aircraft. The Doppler profiles collected by IWRAP at each incidence angle and conical scan will be mapped to a three dimensional grid with a cell size of approximately 150m x 150m x 60m. For each cell, Doppler measurements at the four incidence angles and multiple azimuth angles will be acquired, and from these measurements, the three components of the wind estimated. Surface wind field will be derived from the backscatter imagery collected with each profile. The USFMR provided surface wind speed and rain rate estimates at a one hertz rate.

The UMass CBLAST effort is led by Prof. David J. McLaughlin, with Dr. Alex Xuehu Zhang assisting. Senior Ph.D. student on project is Daniel Esteban Fernandez.

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14. ABSTRACT
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15. SUBJECT TERMS

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WORK COMPLETED

Our CBLAST proposal anticipated funding for FY01 starting on 10/01/2000, but the actual start date for our grant was 05/24/2001. Consequently, FY01 report summarized our accomplishments made over a 4-5 month period rather than an entire fiscal year for our CBLAST proposal. Therefore, this report (FY02) will include progress made on tasks planned for both FY01 and FY02. In our proposal we planed the following tasks for FY01.

1. Boost the transmit power of C and Ku-band from 1 watt to 80 watts by integrating microwave power modules (MPM) into the C and Ku-band transmitters.
2. Incorporate a four channel digital receiver into the IWRAP C and Ku-band receivers to enable IWRAP to simultaneously record the Doppler/reflectivity profiles at four separate incidence angles (approx. 30, 36, 42 and 50 degrees incidence) and two frequencies.
3. Incorporate high power internal calibration loops to IWRAP in order to record transmit waveforms and measure transmitter/receiver gain fluctuations.
4. Test and calibrate IWRAP.
5. Integrate IWRAP into the NOAA WP-3D aircraft.

UMass has completed all tasks proposed for FY01. A major milestone for the project is the completion of IWRAP integration and testing. IWRAP is a dual-frequency fully polarimetric airborne radar with multiple conically scanning beams, capable of imaging radar reflectivity profiles and Doppler velocities of precipitation and ocean surface. Its major parameters are summarized in Table 1

Table 1. IWRAP Parameters

Frequency	C-band and Ku-band
Transmit Power	~ 10W at antenna, ~ 80W at power amplifier output
Pulse Repetition Frequency	1 to 20 KHz
Transmit RF Pulsewidth	125ns to 1us (17.5 to 150 m slant range resolution)
Polarization	Vertically and Horizontally polarized
Incidence Angles	25° – 55°, frequency steered
Conical Scan Rate	30 – 90 rpm
Digital Receiver	12bit A/D at 40 MHz sampling rate
Real-time Processor	Xilinx FPGAs implementing pulse pair processing algorithms

For FY02 we planned for the following tasks:

1. Develop software for processing IWRAP profile data into backscatter images and wind field maps.
2. Participate the 2002 HFP with IWRAP and USFMR.
3. Add dual polarization capability to the IWRAP system.

For FY02, UMass has finished task 3. Task 1 and 2 are in progress at the time of this report. IWRAP and USFMR were flown on board NOAA N42RF WP-3D aircraft during the PACJET/ NOAA NESDIS Ocean Wind Experiment in Feb 2002, and the NOAA HRD CBLAST / NESDIS Ocean Wind (Paul Chang of NESDIS) Hurricane Experiment in August – October 2002. Table 2 and 3 summarizes the data collected in these two experiments.

Table 2. Summary of IWRAP and USFMR Data collected during the 2002 NOAA NESDIS Ocean Winds Experiment.

Flight	Date	IWRAP (Gigabytes)	USFMR (Megabytes)
1	02/02/02	8	54
2	02/04/02	31	49
3	02/08/02	51	55
4	02/09/02	42	21
5	02/15/02	34	63
6	02/18/02	67	66
7	02/20/02	47	41
8	02/21/02	69	85
9	02/25/02	48	61
10	02/26/02	39	70
Total		436 GB	565 MB

Table 3. Summary of IWRAP and USFMR Data collected during the 2002 NOAA HRD CBLAST/NESDIS Ocean Winds Experiment.

Flight	Date	Weather System	IWRAP/SFMR Data
1	08/20/02	Test/Calibration Flight	9 GB
2	09/03/02	TS Eduoard	2 GB
3	09/10/02	TS Gustav	35 GB
4	09/11/02	Hurricane Gustav	37 GB
5	09/13/02	TS Hanna	7 GB
6	09/16/02	TD 10	20 GB
7	09/19/02	Hurricane Isidore	52 GB
8	09/21/02	Hurricane Isidore	34 GB
9	09/22/02	Hurricane Isidore	38 GB
10	09/25/02	TS Isidore	42 GB
11	09/26/02	Calibration Flight (Buoy 42003)	14 GB
Total			290 GB

We have developed and tested a real-time wind vector retrieval software for IWRAP during 2002 Hurricane flights. Real time wind speed and rain rate estimates from USFMR as well as wind direction estimates from IWRAP are currently sent off the P-3 aircraft in near real time to NOAA HRD and NHC scientists. Some of the preliminary results of UMass instruments are shown in next section. We

are currently working on software to process the IWRAP Doppler/Reflectivity profiles into high resolution surface and 3-D wind field.

RESULTS

UMass has developed a dual frequency, fully polarimetic Doppler wind profiling system called IWRAP. IWRAP and USFMR are flown onboard NOAA 42RF P-3 aircraft during 2002 NESDIS Ocean Wind Experiment and 2002 HRD CBLAST experiment. C/Ku-band high resolution (30m slant range) ocean surface and precipitation reflectivity and Doppler data were collected under wind conditions of 0 to 50m/s and rain rates of 0 to 60 mm/hr. Coincidental USFMR and Dropsonde data were also collected. These measurements constitute an unprecedented date set that will enable us to retrieve high resolution surface wind vector field maps and 3-D wind field under the aircraft. We are currently working algorithms to process the IWRAP Doppler/reflectivity profiles into surface and 3-D wind field. UMass has developed near real-time (delay ~ minutes) wind vector retrieval using USFMR and IWRAP. Figure 1 shows the real-time wind estimates of IWRAP and SFMR during hurricane Isidore flight on 09/19/2002. Two Dropsondes data are also plotted in Figure 1 for comparison. It can be seen that IWRAP and SFMR wind speed and direction estimates agree well with Dropsonde measurements. The spiky look of IWRAP estimate is caused by the current retrieval algorithm not compensating for aircraft pitch and roll maneuvers.

IMPACT/APPLICATIONS

The impact of the IWRAP system by UMass is significant in its ability to provide continuous wind and rain profiles along the flight track extending to the surface. It will enable the flux measurements and GPS dropsonde observations of wind and thermodynamics at discrete points along the flight track to be placed in the context of strong gradients, especially in the eyewall. The system will provide truly vertical profiles rather than slant-wise profiles provided by the GPS dropsondes as they are advected by the strong winds. In concert with the USFMR, this system will allow complete mapping of hurricane surface winds for co-location with surface wave spectra measured by the laser altimeter and the SRA operated by other CBLAST scientists on board the research aircraft. These instruments will also provide the bulk variables for comparison with in-situ turbulence measurements as well as the sea spray measurements**.**

TRANSITIONS

The IWRAP/USFMR/Dropsonde data are being used to quantify the effect of precipitation on scatterometry. The results will provide quantitative guidance to marine forecasters and operational users that utilize QuikSCAT wind fields, and thereby improve their confidence in, and utilization of, scatterometer wind field retrievals.

The radar system of IWRAP is being used to guide the design of the node of a weather radar network in an Engineering Research Center (ERC) proposal led by UMass.

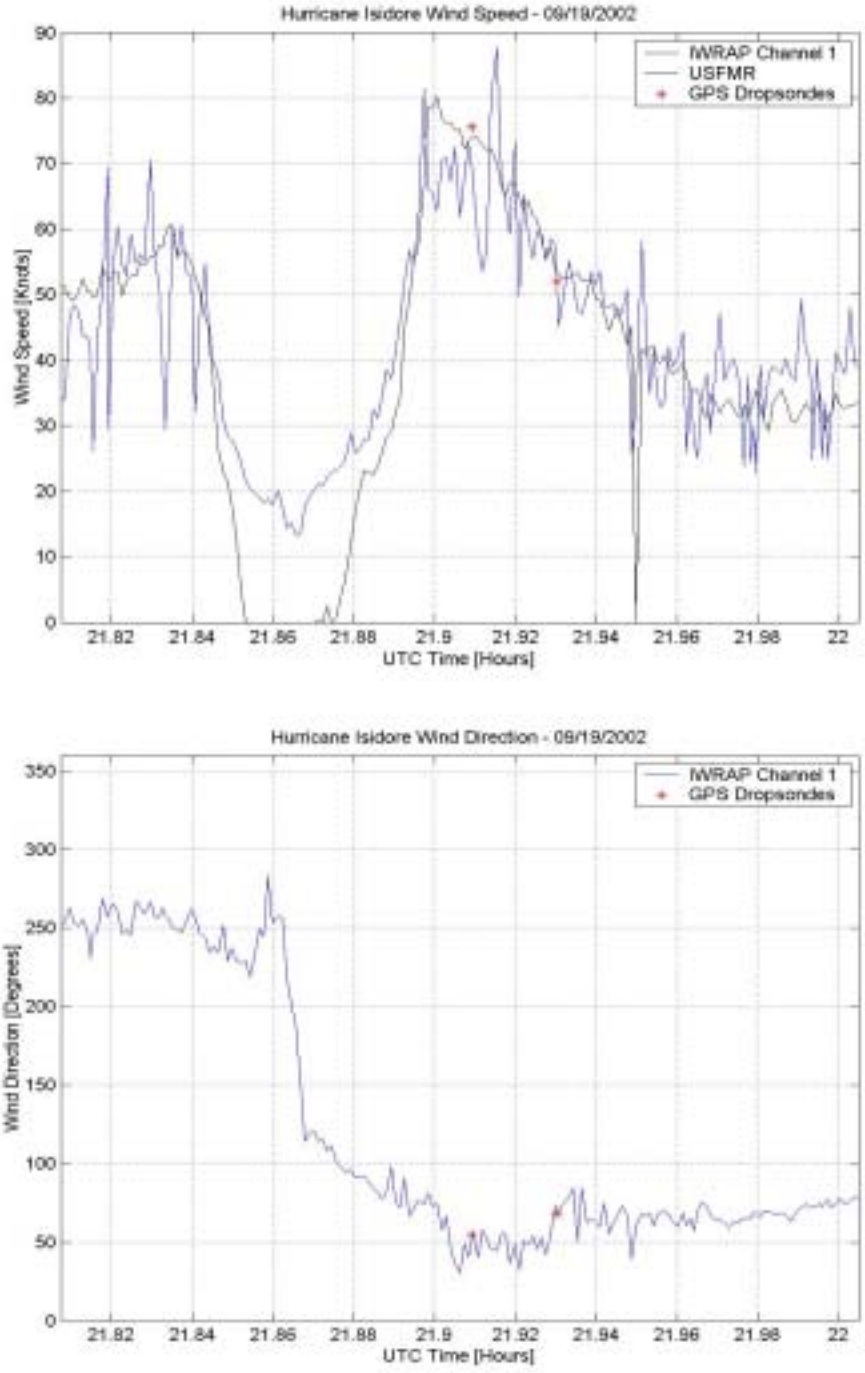

Figure 1. Plots of Real-time wind estimates of IWRAP and SFMR, along with two Dropsonde measurements during Hurricane Isidore flight on 09/19/2002.

RELATED PROJECTS

Air-Sea Flux Estimation in High Wind Boundary Layers, ONR Award #N00014-01-F-009.

Ocean Surface Backscatter Studies in the Presence of Precipitation and High Wind Speeds, NOAA Award.

Atomospheric Profiling of Precipitation at C and Ku-band, NOAA Award, #40-AA-NE108885.
WEB Based Data Archive for the High Wind C-Blast Project, ONR Award, N00014-01-1-0834.

Dual Polarization Upgrade to the UMass Ku/C-Band Airborne Scatterometer, OSU Award (NASA), NS033A-10.

SUMMARY

UMass has completed the construction of the new integrated wind and rain profiler (IWRAP). Simultaneous sampling of ocean surface backscatter and precipitation using active scatterometer (IWRAP), passive radiometer (USFMR) and dropsonds were accomplished by flying UMass's IWRAP and USFMR instruments onboard NOAA N42RF WP-3D aircraft during 2002 NOAA/NESDIS/ORA Ocean Wind Experiment and 2002 NOAA CBLAST/Ocean Wind Hurricane Experiment. Real-time surface wind vector retrieval algorithm is also developed and tested during the experiments. We are currently processing this unprecedented set of remote sensing data to retrieve ocean surface and 3-D wind field.